

10476 ¹²/_A



E S A Y
ON THE
NATURE and wonderful PROPERTIES

OF
Island CRYSTAL,
Respecting its manifold and unusual
REFRACTION of LIGHT.

I**SLAND CRYSTAL** is a Subject of so singular a Nature, that it has attracted the Attention, and excited the Curiosity and Admiration of all Mankind since its Discovery by *Erasmus Bartoline*, about 100 Years ago, who was the first that gave any Account of the Figure and Properties thereof to the Public.

The great **HUGENIUS** soon after published his Treatise on Light (*De la Lumiere*) and gave us therein a more correct and particular Account of this Substance, in regard to its peculiar Forms, Dimensions, and strange Refraction of Light. And because that Book is now rarely

rarely to be met with, and no Extract having been made from it (but a small Sketch in Sir *Isaac Newton's Optics*) that I know of, I have thought my spare Hours could not be better employed than in translating so much of that valuable Work as immediately relates to the Subject of *Island Crystal*; especially as I shall thereby have an Opportunity of adding several new Experiments and Observations concerning its wonderful Properties of Refracting Light.

This Species of Crystal was originally brought from *Island* (or *Ice-land*), an Isle in the Northern Sea, about Latitude 65 Degrees, and from whence it took its Name; but it has been since found in many other Parts of the World, and very plentifully in Great-Britain, particularly in the Peak of *Derbyshire*, though the greatest Part is not very transparent.

The Form of this Crystal or Talk, is that of an *Oblique Parallelopiped*, as represented in Pl. II. Fig. 1. by ACBDEKFL, with six parallelogram Sides, and eight Solid Angles. Two of these solid Angles opposite to one another, as C and E, are compassed each of them by three equal obtuse Angles, each equal to 101 Degrees and 52 Minutes; and the other six Solid Angles, A, L, F, D, B, K, are each contained under one obtuse Angle, and two acute ones of $78^{\circ} 8'$ each.

From the angular Point B let fall a perpendicular BI to the Ground-plane, and through I draw KM indefinitely; then will the Angle BKI be $70^{\circ} 57'$, the Obliquity of the Edge or Line BK of the Solid; and its Complement the Angle IBK will be $19^{\circ} 3'$. Let BK be perpen-



perpendicular to the Side BC, as also the Line *bi*; then the Angle *ibK* was found by exact Measurement to be 105 Degrees, which is the Measure of the Inclination of the Planes ACB and CBKF to each other.

Let a Plane CGHF perpendicular to the Horizon, be supposed to cut the Solid through the Side or Edge CF, then will it evidently bisect the obtuse Angle ACB, and so make the Angles ACG, BCG, of $50^{\circ} 56'$ each. Also it is evident, the Lines KM and FH will be parallel. Draw the Diagonal CH. Then our illustrious Author proceeded to Computation in the following Manner.

Let C be the Vertex of a *triangular* PYRAMID (in the Center of a Sphere) contained under three equal and equi-angular Planes ACB, ACF, BCF, (Fig. 2.) then will the Base of the Pyramid be the spherical Triangle ABF, equilateral and equiangular. And then it is plain that each Angle as A measures or is equal to the Inclination of the two containing Planes ACB and ACF, and each Side of the Triangle as AB is the Measure of the opposite Angle ACB. And further, if any Angle as ACB be bisected by a Line CG, it will of Course also bisect the Side AB, and drawing the Arch FG, it will bisect the Angle at F. In like Manner, if the Side BF be bisected in O, the Arch AO bisects the Angle at A, and cuts the other Arch FG in H, the Pole of the Sphere; and CH is the Semiaxis thereof. Lastly, suppose the three plain Angles which compose the solid Angle C in each Figure the same.

Then because AFB is equal to IBK (in Fig. 1.) or 105 Degrees, the half thereof AFG will be $52^{\circ} 30'$, and the Angles at G being right ones, all the Angles of the right angled Triangle AFG , or BFG , are known, and therefore the Side AF , or BF , will be found to be $101^{\circ} 52'$, which is therefore the Measure or Quantity of each *obtuse Angle* forming the solid Angles C and E in the Island Crystal.

In the same Triangle AFG , the Side or Hypothenuſe FG is found to be $109^{\circ} 3'$, and as this is the Measure of the Angle FCG (Fig. 1.) so its Complement to 180° , viz. $70^{\circ} 57'$ will be the Quantity of the Angle CEH or BKM in the Crystal, and therefore the Angle IBK will be $19^{\circ} 3'$, as we have ſaid.

Laſtly, it is evident the Arch GH (Fig. 2.) is the Measure of the Angle GCH in the Crystal (Fig. 1.) and in the right angled Triangle AGH , there are two Parts known, viz. the Side AG of $50^{\circ} 56'$, and the Angle GAH of $52^{\circ} 30'$, therefore the Side GH will be found to be $45^{\circ} 26'$, and ſuch is the Inclination of the Axis CH to the biſecting Line CG . Theſe are all the Dimenſions of the Crystal neceſſary for our preſent Uſe; and now we proceed to ſpecify and recount the unuſual Properties of Refraction in this ſort of Crystal.

The ſingular Effect of Island Crystal is, that of ſhewing Objects *double* by a *double Refraction of Light*. Diaphanous Bodies in general, as Glaſs, Water, &c. refract a Ray of Light in its Paſſage through them, but they do not divide that Ray into two, and ſo can ſhew only *one*, and not *two different and equal* Images

Images of the same Object, as we always see in the Crystal we now speak of.

The Manner in which this double Refraction is made, is best conceived from the Figure. Let PO be a Beam of Light falling upon the upper Surface AB of the Crystal, in a perpendicular Direction, and in the Plane $FCGH$, which bisects the Angle ACB . Then will this Beam at its Entrance become divided into two, viz. OQ and ON , both which will be in the said Plane FG . The Beam OQ is in the same direction with OP , and goes through the Crystal without Refraction. The other Part or Beam ON is refracted so as to make the Angle QON always equal to $6^{\circ}40'$ very nearly, as is found by Experiment.

If the said Ray falls any where else in the Surface AB , the Refraction will ever be made in a Plane parallel to the Plane FG , so that the refracted Parts will always be in a Line in neither Surface, parallel to the Line FH ; and always make the same Angle equal to QON .

Any Ray cd that falls obliquely upon the Surface, will be refracted in the same Manner, viz. into the two Beams de and df , in a Plane $aDEb$ parallel to $FCGH$, and in an Angle edf equal to the Angle QON .

From what has been said, it evidently follows, that if Q be point in the lower Surface of the Crystal, and directly under the Eye at P , then a Ray of Light proceeding from any Object placed in that Point Q , will in its Passage through the Crystal be divided into the two Parts or Beams QO , QS , of which the Part QO proceeds directly to the Eye without Refraction; but the other is refracted to S , making

ing the Angle OQS equal to QON , in the same Plane FG .

A Ray of Light NO in the Substance of the Crystal will be equally refracted into the Air at each Surface, that is, the refracted Parts OP , NZ will be parallel to each other; therefore since the Ray QS is parallel to NO , it will be refracted into ST parallel to OP , and so the Point Q (or any Object placed in it) will be seen by the Eye by two different Rays of Light OP , ST . Continue the Line TS till it cuts the Line FH in R ; then will the Object at Q be shewn at Q by the Ray QP unrefracted, and at R by the refracted Ray QST , and therefore it *must appear double*.

Let Lg bisect the acute Angle at L , which will therefore be perpendicular to the Line FH ; through Q and R draw two Lines VW , and XY , parallel to Lg ; then it will follow that all the Points Q in the Line VW will be refracted to the Line YX , and consequently the Image of the said Line will be double, or it will appear in the two parallel Lines VW and YX .

If the Crystal were made to move round upon the Point Q , the primary Image of an Object at Q would appear at rest, while the secondary Image at R would be seen to move in a Circle round it.

If the Object be a right Line, then the distance between the two lineal Images, viz. QR , will be greatest of all when the Plane of Refraction FG is in a *direct position* before the Eye; the Images being always necessarily parallel, it is plain that while the Crystal moves round upon the Point Q , the moveable Image

XY



XY will approach nearer to the primary Image in the Line **VW**, till at last it coincides with it, and both the Images appear as *one Line*, and that will be when the said Plane **FG** is in a *right Position* to the Eye,

By continuing the Motion of the Crystal, the secondary Image **YX** will separate from the other quiescent one **VW**, and appear on the other Side, encreasing the Distance till it becomes equal to **QR** again, when the Plane **FG** is direct before the Eye, as at first; and upon turning the Crystal another Quarter of a Circle, the said Plane **FG** is again right to the Eye, and two Images coincide in one as before. In short, the moveable Image **YX** will always be parallel to **VW**, during the whole Rotation of the Crystal, about the Center **Q**.

Sir *Isaac Newton* calls the Plane **FCGH** and all others parallel to it, *Planes of perpendicular Refraction*. Let **FCGH** be such a Plane described out of the Crystal (Fig. 3.) and let **PQ** be a Ray of Light falling upon it in **Q**; through the Point **Q**, draw the Perpendicular **BN**, and upon it as a Center describe the Arches **AB**, **IK**; from the Point **A** where the Arch cuts the Ray, draw **AD** perpendicular to **BN**, and it will be the line of the Angle of Incidence **AOB**; let this be divided into five equal Parts, and make **EK** (the Sine of an Arch **IK**) equal to three of those equal Parts, and through the Point **K** draw **OL** which will be one of the refracted Parts of the Beam, and **OM** will be the other Part. It is found by Experience, that the first or most refracted Part

Part OL is always *regular* in its Refraction, or that its Sine of Refraction EK is in the constant Proportion of three to five to the Sine of Incidence AD, however the Angle of Incidence AOB may vary.

But the other Part of the Beam OM is refracted in an irregular and uncertain Manner, as is also found by Experience. We shall therefore for the future speak of the Refraction of *Island Crystal* as distinguished into two Kinds, *regular* and *irregular*.

When two Pieces of Crystal are placed one over the other, and in similar Positions, that is, with their Planes of perpendicular Refraction FCGH, *f c g b*, parallel to each other (Fig. 4.) then an incident Ray AB is refracted through the first regularly in the Beam BD, and irregularly into the Beam BE, as before has been said. At the nether Surface FH of the first Piece, the two Rays will be refracted into two others DK and EI parallel to each other, and to the incident Ray AB.

In this State they fall upon the lower Piece *f c g b*, and are refracted through it without further Division; but the Ray KL is refracted in the regular Manner, and the Ray IM in the irregular one, and at the lower Surface *f b*, they are both refracted into the Air parallel to each other, as before. And this would be constantly the Case with any Number of Crystals placed in like Manner.

If the two Pieces are so posited, that the Planes of perpendicular Refraction are at right Angles with each other, then the Ray KL which before was refracted regularly, will, in this Case, suffer an irregular Refraction; and the

the Ray IM, before irregular, will now be regularly refracted through the lowest Crystal; but still they pass singly through it.

If one of these two Pieces has its Position inverted, or *bf* placed upwards, then will the Ray IE be refracted to L paralld to BD; and DK will be refracted to the same Point L in a Direction parallel to BE in the first Piece; and consequently by two Pieces of Crystal in such Positions, no Image of any Object can appear double.

In all other Positions of the refracting Planes besides those now mentioned, the Rays DK, EI, will be separated each of them into *two*, in passing through the lower Crystal; and therefore any Object seen through two Crystals so posited will appear *quadruple*, or will have four Images.

These are the principal Properties of Island Crystal enumerated by HUGENIUS, and from him by SIR ISAAC NEWTON. But neither of them say a Word of any *colorific Refraction* in Island Crystal, nor mention any thing more than a *double Refraction*, and that through *parallel Surfaces* only. But this Substance has still many, and much more wonderful Properties, than those above-mentioned, and are commonly known; for Island Crystal has a much stronger *colorific Refraction* than Glass; and it is no wonder, since its refracting Power is so much greater; being, as we have said, in the Ratio of *five to three*, whereas that of Glass is but as *three to two*.

Though Island Crystal is of a *talky* Nature, and much softer than Glass, yet it will take a polish little inferior to that of Glass; at least.

it answers for all Purposes and Experiments of Prisms, several of which I have made, and shewn in my public Lectures for many years past.

By these Prisms it appears, that there is not only a *Double* but a *Multiple Refraction* in Island Chrystal; for some of these Prisms held in a Beam of the Sun's Light will separate it into *two* only, each of which produces a coloured *Spectrum* of the Sun much larger, and the Colours more vivid than in those of Glass Prisms of the same refracting Angle. And the Refraction is so nearly equal in the two Beams, that scarce any Difference can be seen in the coloured Images they make of the Sun, a Candle, or other Object.

Again, some Prisms separate the solar Ray into *Four Parts*, or particular Beams of coloured Light, which make *Four Spectrums* of the Sun, all nearly equally coloured and strong. These Prisms make every Object seen through them appear *Four*, and each one coloured, as in a Glass Prism.

Some other Pieces of Island Crystal afford Prisms with a *Sextuple Power of Refraction*; for they will divide a Beam of the Sun's Light into *six separate coloured Beams*, and consequently shew as many coloured Images of the Sun, and of luminous Bodies viewed through them. But these Pieces of Crystal are not very common; I have seen but one that was clear enough to make a good Prism.

The extraordinary Refractions of these different Prisms are represented in Fig. 5, 6, 7.

In Fig. 5, through a small Hole H, in a Window shut ABCD, a Beam of the Sun's Light

Light HE is transmitted to the Prism of Island Crystal *abc*, and is thereby separated into two Parts EF, EG; and these again refracted into the Air, make the two diverging Rays of Light GI, FK, in all the different Degrees of Refrangibility; and these paint the two Images of the Sun I, K, in Colours very intense and lively.

The same Beam of Light HE in Fig. 6. is divided into *four*, and these produce *four* very beautiful *Spectra*, and all of an equal Degree of Light and Tints, nearly, as at I, K, L and M.

In Fig. 7, the same Beam is divided into *six* others, which depict six coloured Images of the Sun upon a Screen; and notwithstanding the same Quantity of Light is now divided into six coloured *Spectra*, which in a Glass Prism, of the same refracting Angle, would make but one, yet it is surprising to observe how strong each Spectrum appears in regard both to Brightness and Colour; and how little it falls short of that in Glass.

And what is still more very remarkable, is, that the *same Piece* of Island Crystal formed into two Prisms, with Angles nearly equal, will shew through one Angle *two Images* only; but through the other, it will exhibit *six*.

I have not been able yet to procure PRISMS of Island Crystal of more than a *Sextuple*, or six-fold Refraction, singly used; but if two Prisms are combined or placed together, so as either to encrease the refracting Angle, or diminish it, they become a *Multiplier* and a *Multiplicand*, and produce a *Number of Images*, according to the Number in each singly.

Thus if one Prism of two Images, and a refracting Angle of 35° , be applied to another Prism of two Images, whose refracting Angle is 20° , the compound Prism will then have an Angle of 65° or 15° , as you please; but in each there will be *four Images*, stronger or fainter, in proportion to the compound refracting Angle.

In like Manner, if a Prism of two Images be properly compounded with a Prism of four, there will result a Prism of *eight Images*, all very distinct, with Colours more or less intense, according to the Quantity of the compound refracting Angle.

Hence also a Prism of two Images applied to one of six, will produce a Prism of *twelve Images*. Again, two Prisms of four Images each, make a compound Prism of sixteen Images. And a Prism of *four* applied to a Prism of *six*, produces a Prism of twenty-four Images. Lastly, two Prisms of *six Images* each, compose one that will exhibit *thirty-six Images*.

We have mention made of a *double Chromatic Refraction* of a Prism made of *Mountain Crystal*, or *Crystal of the Rock*, by Father Beccaria, in *Philos. Trans.* for the Year 1762, p. 486. But he says it agrees in no respect but *Number*, with the Refraction of *Island Crystal*; hence it is plain, this great *Virtuoso* never saw a *Prism of Island Crystal*; for if he had, it would soon have convinced him of its great Superiority both in regard of its refractive Power and Chromatic Quality.

But the most extraordinary of all the strange Properties of *Island Crystal* is next to be

be rehearsed. It has been a Maxim generally adopted by all Optical Writers, *that a Parallelopiped of any diaphanous Substance, having the refracting Power equal upon each of its opposite and parallel Sides, must therefore refract the Rays of Light without sensible Colour.* But this general Law does not hold in Island Crystal as we shall now demonstrate by Experiment.

In Fig. 3, let PO be a Beam of the Solar Rays incident upon the first Surface CG of the Crystal in a dark Room, then will it be divided into two, viz. OL, OM, as has been said; at the opposite and parallel Surface FH there will be another *double but very different Sort of Refraction* of each of the said two Rays at L and M; for Part of the Ray OL will be equally refracted into LQ parallel to the incident Ray OP, after the usual Manner in Glass, &c. but the other Part of the said Ray OL will be unequally refracted from L towards T, as they are in a Prism, according to their different Degree of Refrangibility; and therefore all the Beam LT will appear of various coloured Light in the darkened Room. After the same Manner, on the other Part, the Beam OM will be equally and unequally refracted into the two Parts, MR parallel to PO; and MS of coloured Light diverging from the Point M.

By these three Beams refracted from the second Surface of the Crystal, there will be three different Images of the Hole at P, through which the first Beam enters the Room; for by the Rays refracted in the usual Manner in LQ and MR, the Hole will have a *double Image* at Q and R on the Screen, but entirely *colourless*.

at

at the Distance equal to LM, in the corresponding Parts, from each other.

But the other two Rays LT, MS, paint each of them a *coloured Image* of the Hole in the Shutter, at such a Distance on either Side, as makes the Angles TLQ, RMS of about five or six Degrees; and this different Refrangibility of Rays is strictly agreeable to that in Glass, but in a greater Degree, as before observed. By variously inclining the Surface to the incident Ray, the Angle of Refraction may, on each Side, be varied from two or three Degrees to sixty or seventy.

As these Pieces of Crystal make three Images in a right Line in the Plane of perpendicular Refraction FCGH, and that in the Middle is double; so other Pieces are found, by which this Line of three Images is refracted on each Side into another Line of three Images; and the middle Line of Images is doubled; so that upon the whole, there are no less than *twelve distinct Images* of the Hole of the Window but formed upon the Screen, by twelve separate Rays of Light regularly refracted through the Crystal terminated by parallel Sides.

But that this most amazing of all Optical Phænomena may be more clearly apprehended, I have represented it to the Eye in Fig. 9. where the Images at 1, 2, 3, are those in the Line just mentioned, and which, in the present Piece of Crystal, becomes doubled in the Images 4, 5, and 6. This Line is refracted also *side-way*, so as to form three other Images on each Side, as at 7, 8, and 9, above; and at 10, 11, and 12 below; and all in so regular
a Man-

a Manner, as to form the Mathematical Figure or *Rhombus*, every way similar to that of the Plane of perpendicular Refraction C F H G.

These Images are all of them tinged with variety of Colours, except the two Central ones at 2 and 5, which appear nearly as white as before. They are not equally coloured however, for some are almost wholly red, others yellow, others green, blue, or violet, according as you vary the Inclination of the Surface to the incident Ray. The two Images at 9 and 10 in the acute Angles are very faint, and unless the Object be very bright, cannot be seen; as the *Sun*, a *Candle*, &c.

If you turn the Crystal round an Axis, the whole System of Images moves round with it, as in other Cases; constantly with the red Part of each Image towards the central Hole or Beam, and the Violet the most remote from it.

If Prisms of two, four, or six Images be successively applied to the Parallelopiped of Crystal, they will multiply the Number of Images accordingly in the Rhombus, and produce the Number *twenty-four*, *forty-eight*, and *seventy-two* Images of the Sun or a Candle; the greatest Part of which will be very distinct, and compleatly tinged with regular prismatic Colours, so as to compose a kind of natural *Girandole* of *Painted Luminaries*, infinitely exceeding any Production or Imitation by the Art of Glass.

Besides these now recounted, there are other, and perhaps more strange Refractions of Island Crystal; but to give a Detail of all the Properties that may be observed in this Substance, and



and the multifarious Manner in which it acts upon Light, would be very tedious; especially as I cannot account for any of those already related upon the *common Principles of Optics*. Some peculiar Structure of the Parts of Island Crystal, yet unobserved, or some particular Modification of the Particles of Light which Sir ISAAC NEWTON himself was not apprised of, must certainly make a Part of their latent Cause. How far those numerous fine *Fissures* which may be seen in some polished Pieces, whose Planes are all at right Angles to the Plane of perpendicular Refraction FCGH, and have the same Inclination with the Line CF, and which are beautifully distinguished by Rings of coloured Light; I say, how far such *Fissures* may be concerned in producing such a Diversity of refracting Properties must be left to future enquiry; only it may be observed, that each Fissure severs from the Parallelopiped an *equiangular Prism*, whose Base is similar to the equilateral Triangle FLg, and its refracting Angles equal to FLg or Fg L, viz. $39^{\circ} 4'$. (See Fig. 1.)

As these *Fissures* have never been mentioned by HUGENIUS or NEWTON, and as I have met with but one Piece that will shew them very plain and distinctly, in order that some Idea may be formed of them, they are represented in Fig. 8, by the several *dotted parallel Lines*, such as their Intersections appear to make with the Surface of the Crystal; and at right Angles to the Plane of Refraction DE.

THE END.



ta
i-
h-
-
of
i-
at
-
r-
e
d
o
s
e
y
h
a
t
h
o
g
-
h
t
v
h
h
o
s
o
o
o